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THE RELATIONSHIP OF WEATHER FACTORS TO THE RATE OF SPREAD OF THE ROBIE CREEK FIRE

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ABSTRACT

The Robie Creek Fire in Boise National Forest, Idaho, September 5–9, 1955, is described, and concurrent weather conditions are analyzed. The fire exhibits four different types of behavior during the five days. On four of the days, the behavior follows patterns previously recognized as being usually associated with the prevailing weather conditions. The exceptions occur on the third day, which is meteorologically similar to the second day but exhibits a different fire behavior. Some implications that this study has for forecasting and research are pointed out.

1. INTRODUCTION

Many observations have been made regarding the cause of forest and range fire spread and a number of well-qualified men have made investigations and contributed valuable reports and technical papers on this complex subject. There is general agreement that weather is the most important variable in fire spread, and that the conditions which lead to "blow-ups" are very complex and difficult to predict.

This paper consists of a report of the weather conditions which existed during the Robie Creek Fire in the Boise National Forest, Idaho, September 5–9, 1955, and an analysis of the relationship of those conditions to the fire behavior.

There are several reasons why this fire adapts itself to an analysis of this type: (1) The fire occurred only 10 to 15 airline miles northeast of the Boise Weather Bureau Airport Station where regular surface and upper air observations are made. (2) The fire area was bracketed by two fire-weather stations, Shafer Butte Lookout, six miles north of Robie Creek at an elevation of 7,590 feet, and Idaho City Ranger Station some 12 miles northeast of the fire, at an elevation of 3,950 feet, in the main Mores Creek Drainage. (See fig. 1.) (3) The fire went through four different types of behavior-day: a blow-up, a long run, a potentially critical but quiet day, and a quiet day.

2. DESCRIPTION OF THE FIRE

The Robie Creek Fire in the Boise National Forest started in the early afternoon of Labor Day, September 5, 1955. It was a hot, dry day; the 45th day since there was measurable precipitation in that area and the 21st consecutive day with the maximum temperature above normal. The maximum temperature at nearby Idaho City Ranger Station that day was 101° F. and the relative humidity was 6 percent resulting in a very high fire danger (Burning Index of 72 on the Forest Service Model 8 Meter).

The fire apparently started on the east side of the Boise Ridge and at a point on a minor slope exposed to the southeast. The point of ignition was in well-cured grass in a light stand of chokeberry brush. Fuel in the general area consisted mostly of dry grass, several kinds of brush, and second growth Ponderosa pine. The fire started at an elevation of about 5,000 ft., but eventually spread over an elevation range from 4,000 to 5,500 ft. Although winds were light and variable, the other factors were very conducive to fire spread. Within two hours of the time that fire began there were 15 to 20 people from the nearby

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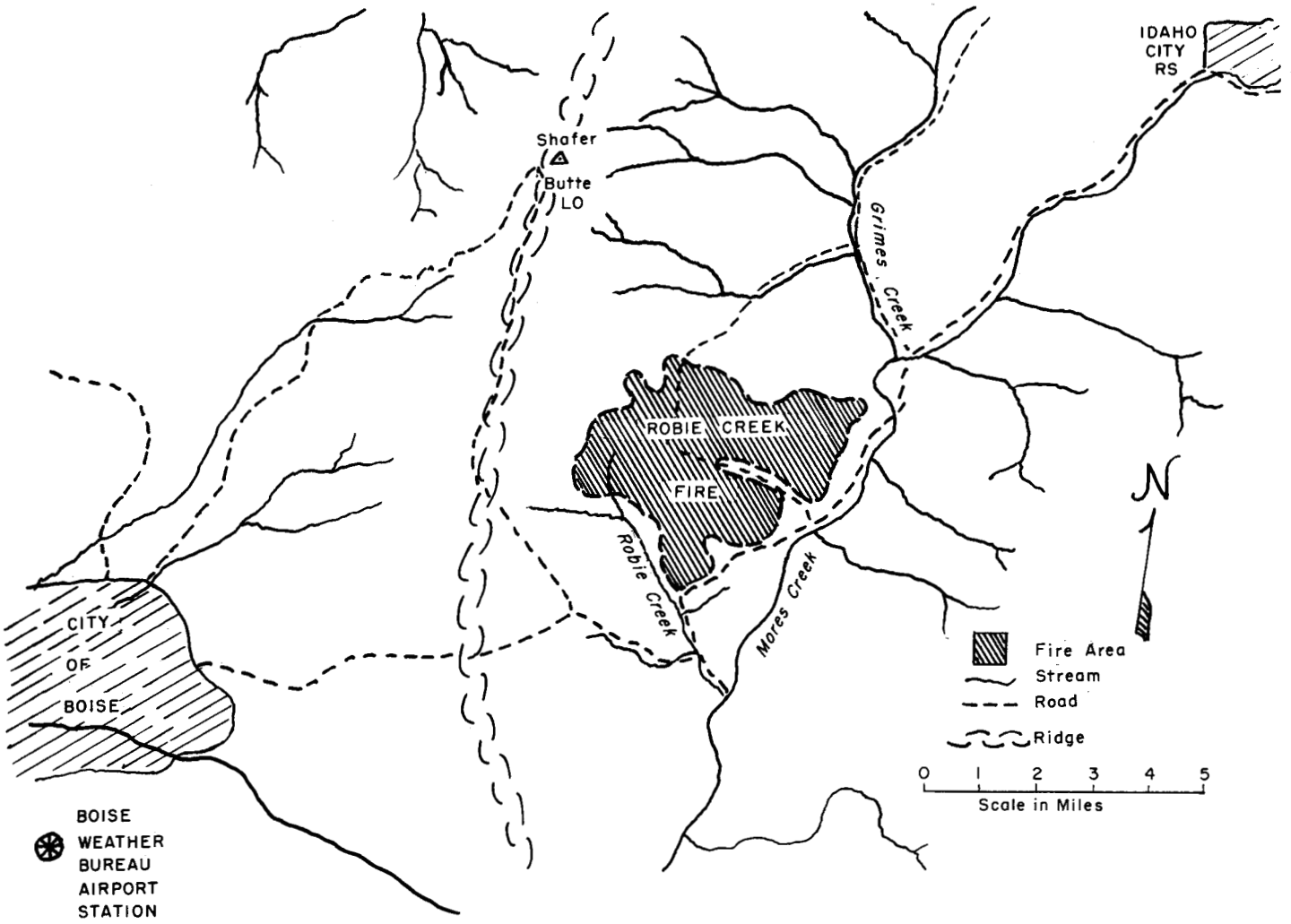

FIGURE 1.—Sketch of general region surrounding Robie Creek Fire area, Boise National Forest, Idaho.

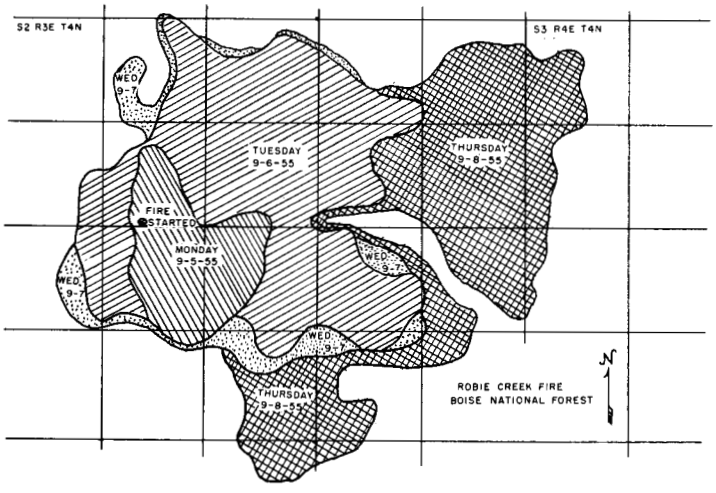

FIGURE 2.—Total area of the Robie Creek Fire showing location where fire started on Monday, September 5, 1955 and its spread on succeeding days. Grid interval equals 1 mile.

Karney Lakes Resort, four smoke jumpers, and a crew of 20 trained fire fighters at the scene, but the rate of spread was so great that the fire fighters had to retreat from the fire area.

The fire started on Monday, September 5 and was brought under control on Friday, September 9. Of the five days, major runs or "blow-ups" occurred on three days: Monday, Tuesday, and Thursday. On Wednesday there were minor flare-ups, but no sustained run occurred. There was very little spread on Friday as established lines were widened and mop-up commenced (see fig. 2).

During the five days the fire spread over 8,310 acres of private and National Forest land. At the peak of the attack over 700 men were employed and total suppression costs were in excess of $100,000.

3. WEATHER CONDITIONS

In the attempt to determine which weather parameters had the most influence on the fire behavior during the 5-day period, comparisons were made of the various weather data.

On the assumption that stability would be an important factor, a comparison was made of the twice-daily Boise radiosonde observations (fig. 3). The lapse rate was very nearly dry adiabatic on Monday, Tuesday, and Wednesday and only slightly more stable on Thursday and Friday. Since the fire made big runs on Monday, Tuesday, and Thursday it appears that something more than stability was involved. On Thursday when the fire made one of its largest runs the lapse rate was less than on the preceding three days. The daily lapse rates were compared by layers but nothing of significance was indicated.

Another approach to the stability factor was made by plotting the Shafer Butte, Idaho City, and Boise WBAS maximum temperatures on the appropriate tephigram at the proper temperature and elevation point. (See fig. 3.) On Monday and Tuesday the temperature at both Shafer Butte and Idaho City was considerably warmer than that shown at corresponding levels on the 2000 MST Boise radiosonde observation. On the assumption that the Boise sounding was representative of the air over those two stations (see fig. 1), superadiabatic lapse rates apparently existed near the surface at the two stations. On Wednesday and Thursday this apparent superheating effect was considerably reduced.

Comparison was also made between the Shafer Butte and Idaho City 1600 MST relative humidity and maximum temperatures for each of the days, but other than to show that it was hot and dry all five days the significance in relation to fire spread was not readily apparent. (See table 1.) The maximum temperatures were highest on Monday and Tuesday, about 8° lower on Wednesday, and 5° to 10° lower still on Thursday and Friday. The afternoon relative humidity was low throughout the period ranging from 6 percent at Idaho City on Monday, to 12 percent on Tuesday and Wednesday, up to 26 percent on Friday. The Shafer Butte relative humidity varied from 11 percent on Monday, to 14 percent on Tuesday and Wednesday, up to 40 percent on Friday.

The wind speed profiles for the 0800 MST and 1400 MST Boise winds aloft observations are shown in figure 4. The wind speeds above 7,000 ft. m. s. l. increased gradually during the first four days of the fire and then slacked off again at the end of the week. The winds aloft show a closer correlation to fire behavior than any of the other factors and that relationship is discussed later in connection with Byram's Wind Speed Profile Types.

TABLE 1.—*The maximum temperature and 1600 MST relative humidity for the five days of the Robie Creek Fire, Boise National Forest, Idaho*

		Monday 9/5/55	Tuesday 9/6/55	Wednesday 9/7/55	Thursday 9/8/55	Friday 9/9/55
Boise Weather Bureau Airport Station	Max.	97°	98°	97°	81°	80°
	R. H.	24%	23%	17%	27%	30%
Idaho City Ranger Station	Max.	101°	100°	92°	80°	81°
	R. H.	6%	12%	12%	19%	25%
Shafer Butte	Max.	84°	83°	77°	62°	62°
	R. H.	12%	14%	14%	34%	40%

4. FIRE BEHAVIOR

The fire behavior on Monday was very similar to that of Tuesday and most of the weather data were strikingly similar on those two days, except for minor changes in the winds aloft patterns. The fire covered considerably more acreage on Tuesday than on Monday, but that difference was probably due to the fact that the fire started from zero area on Monday afternoon while it was well established with several miles of front on Tuesday. See figure 2. Monday and Tuesday both had some of the characteristics associated with a blow-up pattern; i. e., steep lapse rates, high temperatures, low humidity, dry fuel, and relatively light winds aloft. On both Monday and Tuesday the major spread occurred in the middle and late afternoon and was accompanied by a nearly vertical smoke column which was topped by a well-developed cumulus cloud (see fig. 5). Both Monday night and Tuesday night the smoke filled the surrounding valleys and remained low until upslope motion commenced at 1000 MST on Tuesday and 1100 MST Wednesday.

On Wednesday the fire spread over only about 500 additional acres compared to over 3,000 acres on Tuesday. However, the temperature lapse rate was almost as steep as on the previous two days and the minimum relative humidity at Idaho City and Shafer Butte was the same as on Tuesday. There were minor changes in maximum temperature with a drop of 6° at Shafer Butte and 8° at Idaho City. Winds aloft were weaker at low elevations and stronger at high elevations as shown by the wind speed profiles. On Wednesday there was no towering cloud-capped smoke column, only small areas of billowing smoke during the afternoon. In contrast to the previous nights the fire continued to spread during the night, especially near the ridge tops, and there was very little smoke hanging in the valleys Thursday morning.

On Thursday cooler air was obviously moving into the fire area with moderate westerly winds across the Boise Ridge and down onto the fire. In the early morning the fire was moving rapidly up the slopes exposed to the west and throughout the morning and afternoon the fire continued to spread in an easterly direction. Maximum temperatures were down about 20° from Tuesday and minimum relative humidity was up 10 percent to 20 percent. Although the fire covered nearly as great an area on this day as on Tuesday the behavior was different. The wind was relatively consistent in both speed and direction and the fire moved from west to east, up slope and down. The forest officials described it as more of a steady "push" than a blow-up. The smoke column leaned to the east and although small cumulus tops appeared frequently they disappeared almost as quickly as they formed. See figure 6.

On Friday winds were light and variable, temperatures were about the same as on Thursday, and the relative humidity was higher by 5 percent to 10 percent. In the

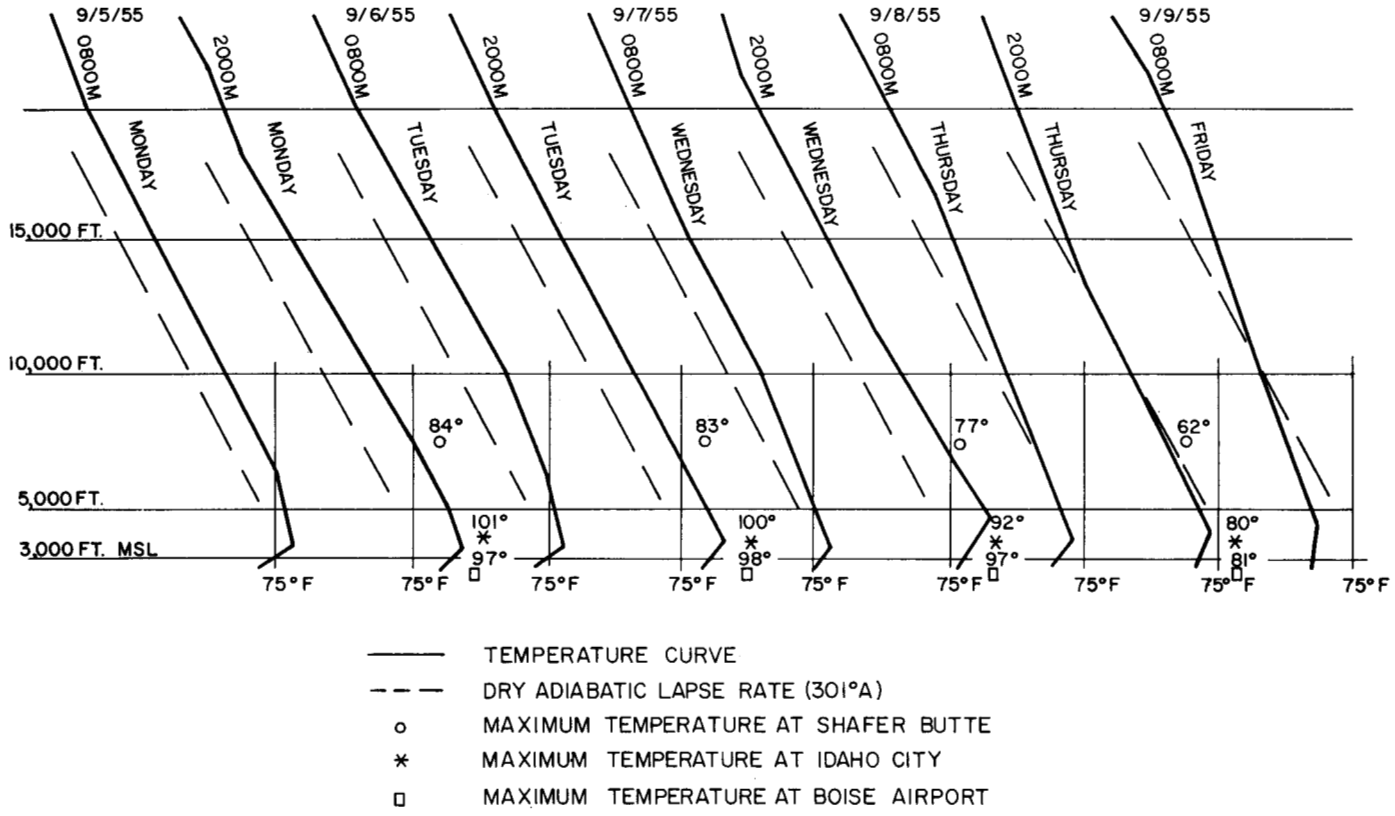

FIGURE 3.—Radiosonde temperature observations at Weather Bureau Airport Station, Boise, Idaho during period of Robie Creek Fire. Daily maximum temperatures for Shafer Butte Lookout, Idaho City Ranger Station, and Boise Airport are plotted at their relative elevations.

afternoon a few minor dust whirls (fig. 7) were visible in the ashes and smoke stumps, but at no time was there a serious flare-up or threat to the fire lines. By this time the suppression attack was organized and lines were well-established and manned. However, portions of the line would probably have been vulnerable to a strong wind or blow-up development.

5. DISCUSSION

There is considerable difference in opinion among fire control experts as to just what constitutes a "blow-up". Definitions range from an actual explosion of hot gases, to a fire that is merely burning out of control. Arnold and Buck [1] define blow-ups as "fires which exhibit violent build-up in fire intensity or rate of spread sufficient to prevent direct control by efficient application of conventional fire fighting methods." By this definition conditions that could be classed as blow-ups occurred in the Robie Creek Fire on Monday, Tuesday, and Thursday, although the associated weather conditions and fire behavior were not the same.

On the first two days the smoke column went almost directly upward and the cumulus cloud cap continued to build and spread until dissipation set in at sundown. There appeared to be a "chimney effect" reaching to an estimated 25,000 to 30,000 ft. which induced a strong draft at the base of the column. Wind speeds in the free air at Boise were 9 to 12 m. p. h. at the fire level and at Shafer Butte the speed at 1600 MST was estimated at 8 m. p. h. on Monday and 14 m. p. h. on Tuesday.

As previously mentioned, the spread on Thursday was from west to east with the smoke diffused over a wider area and with a definite slope to the smoke column. Winds in the free air at fire levels were from the west 14 to 22 m. p. h. and at 1600 MST Shafer Butte reported southwest 20 m. p. h.

Arnold and Buck [1] have listed five atmospheric situations under which fire blow-ups may occur:

1. Fire burning under a weak inversion.
2. Fire burning in hot air beneath a cool air mass.
3. Combustible gases from a fire accumulating near the ground.
4. Fire exposed to a steady-flow convection wind.
5. Fire burning near a cell of vertical air circulation.

The rapid spread on Monday and Tuesday corresponded to situation 5, and the conditions on Thursday seemed to fit situation 4.

Byram [2] states that for the greatest blow-up potential the wind should reach a maximum within the first 1000 ft. above the fire and then decrease in speed with elevation for the next several thousand feet. He refers to this point of maximum wind speed immediately above the fire as the

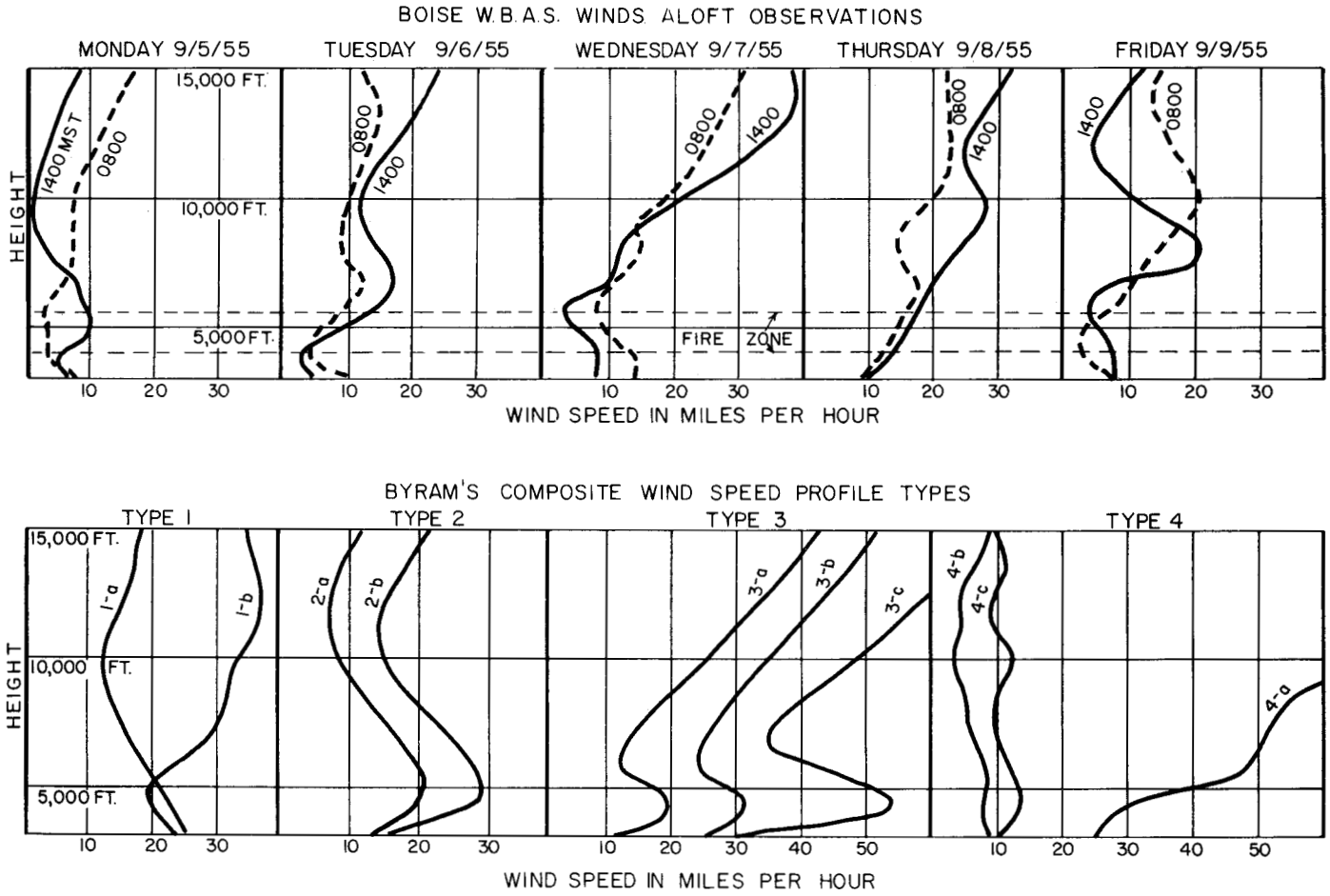

FIGURE 4.—Daily winds aloft observations taken at Weather Bureau Airport Station, Boise during period of Robie Creek Fire (upper graphs) compared with Byram's wind speed profile types.

"jet point" and states that the wind speed near the jet point for most dangerous fires will be 18 to 24 m. p. h. for light to medium fuels. Byram has classified the wind speed profiles into four main types, each with two or more sub-types (see fig. 4).

In comparing the wind speed profiles of the 1400 MST Boise winds aloft reports for the five days of this discussion we find that the profile for Monday closely resembles Byram's Type 4-c which ". . . is 'safe' as long as the jet point wind is below 15 m. p. h. . . . except in case of a fire burning up slope in same direction as general wind is blowing in which case 4-c may be converted to the dangerous Type 1-a." Although the wind on the Robie Creek Fire was below the mimima listed by Byram, the fire was burning up slope with the wind and it had many of the characteristics of his Type 1-a.

The wind speed profile at 1400 MST on Tuesday for Boise closely resembles Byram's Type 3-a with the jet point just above the fire zone. This type has strong winds at high levels, but with a layer of decreasing speed just above the jet point. Byram says of this particular profile ". . . for a fire near 7,000 feet it resembles the dangerous Type 1-a and it is doubtful if the wind speeds at high levels are strong enough to shear off the convection column." Type 3-a and 3-b may be accompanied by strong whirlwinds and rapid fire spread when jet point winds are 20 m. p. h. or more. The winds at the jet point level at Boise Weather Bureau Airport Station were below Byram's minima, but speeds must have been higher just above the fire. Fire crews reported "spotting" as much as a quarter of a mile ahead of the fire Tuesday afternoon which would indicate some of the whirlwind activity mentioned by Byram.

On Wednesday the wind speed profile resembles Byram's Type 1-b, except that wind speeds in the fire zone were much below the limits shown. The strong winds above 10,000 ft. would tend to prevent formation of a convection column which might induce strong winds at the surface. Colson [3] states ". . . the convection column will not attain great heights if the wind speed increases too rapidly with height. Too strong a wind speed may cause the column to be broken away from its energy source."

Byram's Type 4-a resembles the wind speed profile and also the fire behavior on Thursday. Regarding Type 4-a Byram states ". . . fires were intense and fast-spreading, but they could not be considered dangerous to experienced crews, nor was there any erratic and unusual aspects to their behavior." On the 1400 MST profile there was a jet

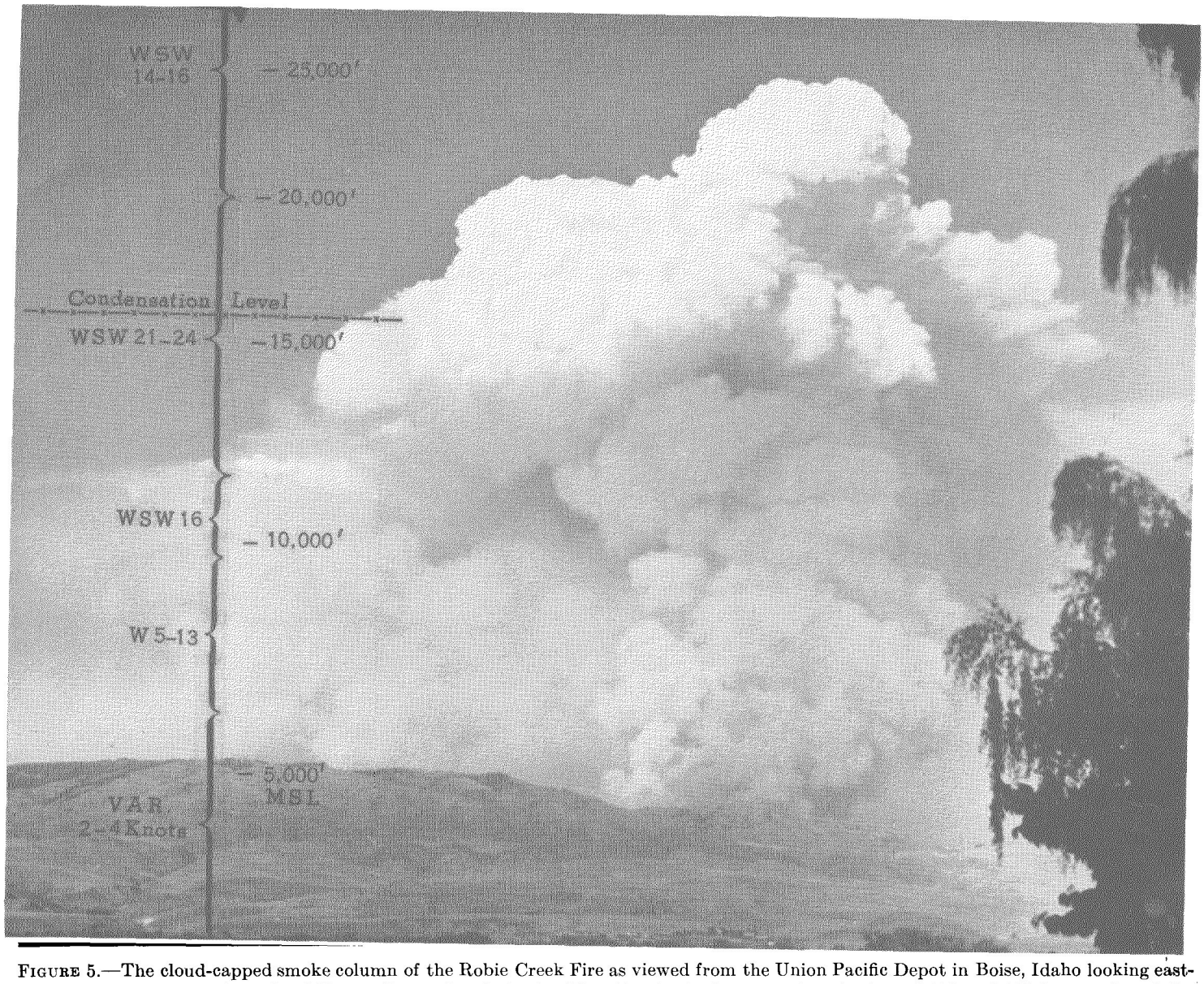

FIGURE 5.—The cloud-capped smoke column of the Robie Creek Fire as viewed from the Union Pacific Depot in Boise, Idaho looking east-northeast at approximately 1800 MST, September 6, 1955. The ridge in the foreground varies from 5,000 to 6,000 ft. m. s. l. and the top of the cloud was estimated from theodolite readings to be near 25,000 ft. The height scale on the picture is compressed some near the top to compensate for the slope of the smoke column and cloud away from the camera. Wind velocity and condensation level shown are taken from the 2000 MST rawin observation made at Boise Airport. (Photo by Russel M. Short.)

point at 10,000 ft., but it was too far above the fire area to develop the characteristics of Byram's Types 2 or 3.

The speed profile at 1400 MST on Friday closely resembles Byram's Types 1-a or 2-a for the area above 7,500 ft., but fortunately the fire zone was below 5,500 ft. where the winds were light.

In this application of Byram's Wind Speed Types to the Robie Creek Fire we have not considered wind direction and in most cases actual wind speeds were below those specified for his types. His classifications explain the fire behavior during most of the fire period, but from the forecaster's standpoint it would be difficult to predict some of the minor differences among these types.

The fire behavior on Monday, Tuesday, Thursday, and Friday followed previously recognized patterns usually associated with the prevailing weather variables. However, the meteorological similarity between Tuesday and Wednesday was remarkable while the fire behavior was very different. Following is a comparison of the two days:

1. Fuel conditions on Wednesday were essentially the same as on Tuesday with fuel remaining on all sides of the fire. Lines had been established on some of the fire boundary, but the long run the following day indicates that the spread potential was present.

2. Figure 3 indicates that stability was not the differentiating factor.

3. Minimum relative humidity was the same both days.

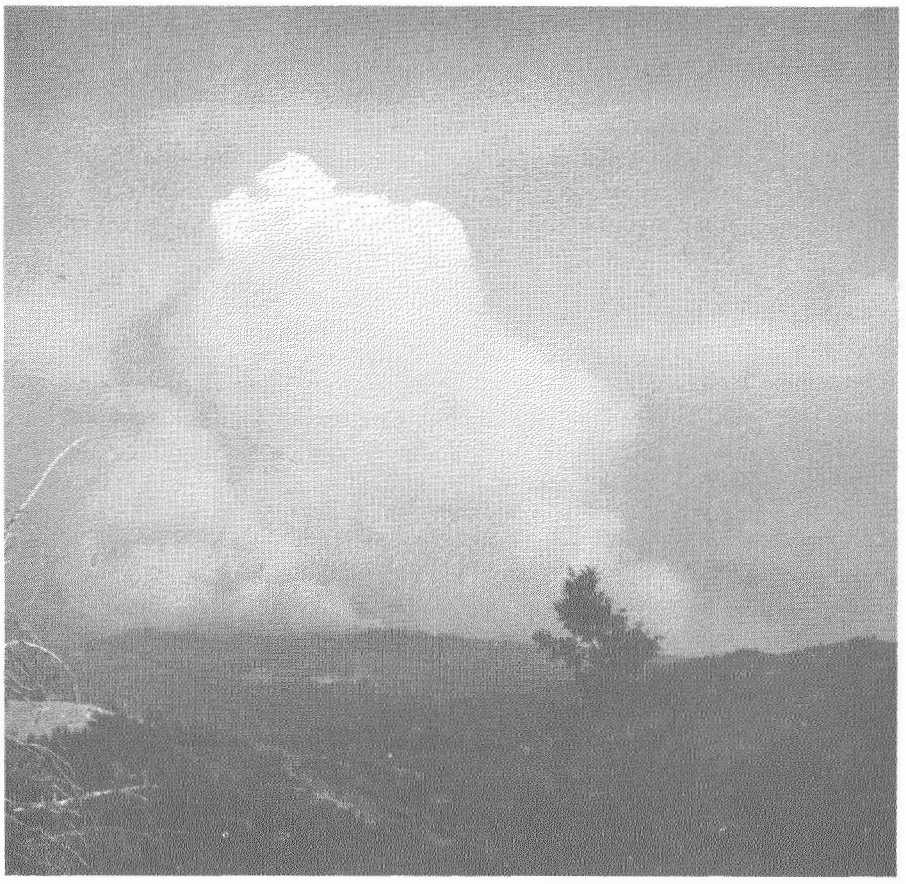

FIGURE 6.—Looking southeast toward the Robie Creek Fire from near Shafer Butte Lookout, Thursday, September 8, 1955 at 1715 MST. Note smoke column leaning toward the east. (Photo by John H. Dieterich.)

FIGURE 7.—Dust whirl in ashes behind fire lines near a ridge top. Robie Creek Fire, Friday, September 9, 1955 at 1410 MST. (Photo by John H. Dieterich.)

4. Maximum temperatures were the same at Boise and 5° to 8° lower at Idaho City and Shafer Butte on Wednesday, but that change in itself hardly seems great enough to be critical.

5. The winds aloft at Boise Weather Bureau Airport Station show minor differences in direction on the two days, but wind speed profiles (fig. 4) varied considerably. Byram's wind speed profile types are different for the two days and they offer probably the best explanation for the variation in fire behavior between the two days.

6. A study of the pattern of the maximum temperature distribution between Boise Weather Bureau Airport Station, Idaho City Ranger Station, and Shafer Butte Lookout shows another difference between Tuesday and Wednesday. See table 1.

When the maximum temperatures were plotted on the tephigram with the Boise radiosonde observations (fig. 3) it appeared that there must have been a super-adiabatic lapse rate near the surface at Idaho City and Shafer Butte on Monday and Tuesday which was not nearly so pronounced on Wednesday. This super-heating effect was at a maximum on Monday and Tuesday, was at a minimum on Wednesday, and gradually increased again on Thursday and Friday. Surface winds at the three points do not explain this difference, nor were there any obvious differences in microclimatic effects at the different exposures. There currently seems to be no ready explanation for those variations in super-heating, but that factor did vary with the rate of spread of the Robie Creek Fire.

6. CONCLUSIONS

Monday and Tuesday, the first two days of the Robie Creek Fire, were examples of the convective-column type blow-up days with light winds, steep lapse rates, high surface temperatures, and critical wind speed profiles.

Fire behavior on Thursday was an example of a long fire run resulting from a strong and persistent horizontal wind accompanying the advection of cooler air into the fire area.

Friday was a day with unstable lower layers and light wind at critical levels, but with no spread difficulties encountered on the fire lines. Wind whirls were visible in the ash and smoke in some areas inside the fire lines and conditions of wind, temperature, and stability fit closely most of the conditions favorable for fire whirlwinds as described by Graham [4] and Byram [2]. Fortunately the whirlwinds did not occur in the vicinity of hot fire and heavy fuel.

Fire behavior on Wednesday does not fit into the accepted pattern usually associated with the prevailing

conditions of temperature and stability, but, as indicated by Byram, the wind speed profile was one that would favor fire control with light winds in the fire zone and strong winds at high levels.

Presently there is no satisfactory explanation at hand for the differences in the maximum temperature distribution pattern between Boise, Idaho City, and Shafer Butte. Since this temperature pattern did appear to vary with the rate of fire spread, a logical explanation might serve as a forecasting aid.

The principal objective in an analysis of this type is to develop means of improving forecast and warning techniques. Byram's wind speed profiles have considerable merit, as the evidence has shown, but a careful examination of the wind speed profiles for the 0800 MST wind observations indicates the presence of a "jet point" on each of five days. On Monday, Wednesday, and Friday the jet point moved down 1,000 ft. or more between 0800 MST and 1400 MST while on Thursday it moved up 3,000 ft. and on Tuesday it remained at the same elevation. From a forecaster's standpoint it would be difficult to separate the blow-up days from the quiet days on the basis of projected 0800 MST wind speed profiles, although this is a field in which further study seems warranted.

This study indicates that the forecasters on large fires should consider carefully the wind speed profiles and surface temperature distribution as well as temperature lapse rates, surface weather charts, and other observational material. If it were possible to dispatch a mobile rawinsonde observational unit to large fires the information gained would be very valuable to the forecaster in predicting fire behavior. The cost of constructing and operating a mobile rawinsonde unit would be considerable, but in view of the terrific property losses and suppression costs on large fires, such a unit would be justified. Pilot balloon observations would be impractical because of visibility restrictions, and only very rarely does a large fire occur close enough to an upper air observational station to make the data representative of conditions over the fire.

ACKNOWLEDGMENTS

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Mariners Weather Log

A new bi-monthly publication containing meteorological information for the maritime industry, including weather and shipping on the Great Lakes as well as oceanic areas, recently began issuance under the title *Mariners Weather Log*. The first issue was dated January 1957. Each issue usually contains two major articles and several smaller contributions of current maritime interest. Recent ocean weather is described and a table of selected ship gale observations is included. Annual subscription, $1.00; additional for foreign mailing, 25¢; 20¢ per copy. Orders should be addressed to Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.